Should agricultural policies encourage land sparing or wildlife-friendly farming?

Joern Fischer[1*], Berry Brosi[2], Gretchen C Daily[2], Paul R Ehrlich[2], Rebecca Goldman[2], Joshua Goldstein[2], David B Lindenmayer[1], Adrian D Manning[1], Harold A Mooney[2], Liba Pejchar[2], Jai Ranganathan[2], and Heather Tallis[2]

As the demands on agricultural lands to produce food, fuel, and fiber continue to expand, effective strategies are urgently needed to balance biodiversity conservation and agricultural production. "Land sparing" and "wildlife-friendly farming" have been proposed as seemingly opposing strategies to achieve this balance. In land sparing, homogeneous areas of farmland are managed to maximize yields, while separate reserves target biodiversity conservation. Wildlife-friendly farming, in contrast, integrates conservation and production within more heterogeneous landscapes. Different scientific traditions underpin the two approaches. Land sparing is associated with an island model of modified landscapes, where islands of nature are seen as separate from human activities. This simple dichotomy makes land sparing easily compatible with optimization methods that attempt to allocate land uses in the most efficient way. In contrast, wildlife-friendly farming emphasizes heterogeneity, resilience, and ecological interactions between farmed and unfarmed areas. Both social and biophysical factors influence which approach is feasible or appropriate in a given landscape. Drawing upon the strengths of each approach, we outline broad policy guidelines for conservation in agricultural landscapes.

Front Ecol Environ 2008; 6(7): 380–385, doi:10.1890/070019

The need to balance biodiversity and agriculture has never been greater. In the past 40 years, the human population has doubled to 6.5 billion, and is projected to grow to 9.2 billion by 2050 (Population Reference Bureau 2006). Humanity's increasing demand for food and fuel puts pressure on ecosystems around the world (MA 2005). Alongside climate change, land conversion for agriculture poses the greatest threat to terrestrial biodiversity (Foley *et al.* 2005), and it is projected to intensify on many fronts, from subsistence to large-scale biofuel production (Ragauskas *et al.* 2006). The threats involved in land conversion are considerable, because biodiversity generates ecosystem conditions, functions, and services essential to agriculture, such as nutrient recycling, pest control, pollination, and the regulation of water flows (MA 2005). Given the intimate links between agriculture and biodiversity, strategies are urgently required to balance the two.

In a nutshell:

- "Land sparing" and "wildlife-friendly farming" are hotly debated as two alternative approaches to simultaneously promote biodiversity conservation and agricultural production
- The two approaches are related to different scientific world views, and have unique advantages and disadvantages
- Social factors and biophysical properties of landscapes strongly influence which agricultural policies are possible
- Recognizing these constraints, we outline policy guidelines that draw on key strengths of both land sparing and wildlife-friendly farming

[1]*The Fenner School of Environment and Society, The Australian National University, Canberra, Australia* [*]*(joern.fischer@anu.edu.au);* [2]*Department of Biological Sciences, Stanford University, Stanford, CA*

Waggoner (1996) first coined the phrase "sparing land for nature" from agricultural production. More recently, a high-profile paper by Green *et al.* (2005) revived this phrase, sparking renewed debate about how agriculture and biodiversity should be integrated (Balmford *et al.* 2005; Matson and Vitousek 2006; Dorrough *et al.* 2007; Vandermeer and Perfecto 2007). Green *et al.* (2005) framed the balancing act between agriculture and biodiversity as a trade-off between two contrasting management options: land sparing and wildlife-friendly farming.

In land sparing, agricultural areas are used intensively. This results in a high agricultural yield from a relatively small area of land, thereby allowing for the permanent preservation of species-rich areas nearby (Green *et al.* 2005). Farmland in intensive systems tends to support relatively few species of macrofauna (Benton *et al.* 2003; Eggleton *et al.* 2005; Tscharntke *et al.* 2005), although the diversity of microbes can remain quite high (Tiedje *et al.* 1999).

In wildlife-friendly farming, agricultural yields tend to be lower per unit area (Green *et al.* 2005; but see Perfecto *et al.* 2005). Therefore, a larger land area is typically needed to produce the same agricultural yield. While this leaves less land for permanent preservation, more biodiversity can occur on the "wildlife-friendly" farmland itself (Green *et al.* 2005).

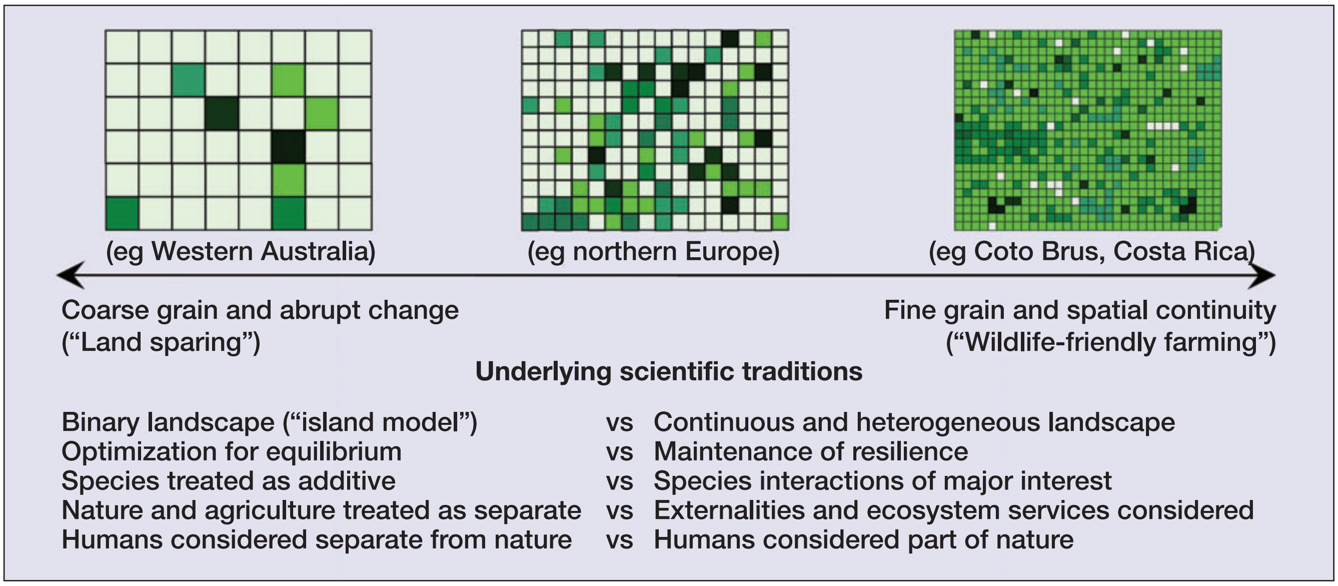


Figure 1. *Conceptual model of the continuum of scales at which biodiversity conservation and agriculture can be integrated. Land sparing and wildlife-friendly farming can be considered endpoints on this continuum. The shade of green denotes the value of a given grid cell for biodiversity conservation, with darker shades representing greater value. Different scientific traditions underlie the endpoints of the continuum. These traditions influence how the task of balancing biodiversity and agriculture is conceptualized and accomplished, but they are rarely drawn out explicitly.*

Which of these two approaches should be encouraged by agricultural policies? In the current debate, land sparing and wildlife-friendly farming are seen as contrasting approaches to land management. Given this debate, our aim is to provide a balanced overview of the typical characteristics, conceptual basis, benefits, and limitations of each system. We conclude by outlining some general policy guidelines for agricultural landscapes that draw on the strengths of both approaches.

Typical characteristics of land sparing and wildlife-friendly farming

Although there will be exceptions, it is useful to make some broad generalizations about typical characteristics of landscapes managed according to the approaches of land sparing and wildlife-friendly farming.

In land sparing, agricultural land is managed for commodity production rather than biodiversity conservation. Agricultural yields on farmland are maximized so that other areas can be "spared for nature" (Waggoner 1996; Green *et al.* 2005). The resulting agricultural systems are typically industrial in style and strive for maximum economic efficiency. They commonly rely on high inputs of fertilizers and pesticides, crop diversity is usually low, and individual fields tend to be large. Biodiversity in such landscapes is largely restricted to nature reserves that are intentionally set aside from agriculture. Nature reserves often occur on government-managed land, because there is little short-term economic incentive for farmers to manage substantial blocks of land for conservation.

Wildlife-friendly farming may or may not be conducted with the specific intention of conserving wildlife. However, irrespective of the underlying intention, the term does imply that whatever farming practices are used do benefit wildlife and, presumably, biodiversity more generally, in some way. Typical characteristics of wildlife-friendly agricultural landscapes include patches of native vegetation scattered throughout the landscape, farmed areas that are structurally similar to native vegetation, and a high level of spatial heterogeneity (Luck and Daily 2003; Fischer *et al.* 2006). This heterogeneity may be achieved by planting a diversity of crops in a range of small fields, retained habitat features within fields (eg scattered trees), or habitat features along the margins of fields (eg hedgerows; Benton *et al.* 2003; Harvey *et al.* 2006; Manning *et al.* 2006).

Land sparing and wildlife-friendly farming represent the endpoints of a continuum of separation between agriculture and biodiversity (Figure 1). Three emergent characteristics summarize the main differences between land sparing and wildlife-friendly farming. First, in land sparing, there is a strong contrast between land for agriculture and land for biodiversity, whereas this disparity is less pronounced in wildlife-friendly farming, and agriculture and biodiversity co-occur in the same area. Second, in land sparing, agricultural land itself is essentially homogeneous, whereas it is typically much more heterogeneous under wildlife-friendly farming. Third, variability in land cover and its value for biodiversity are at a finer spatial scale, or grain, in wildlife-friendly farming than in land sparing (Figure 1).

Examples of landscapes occupying different parts of this continuum are shown in Figure 2. One instance of land sparing occurs in Western Australia's wheatbelt. Apart from designated nature reserves, much of the agricultural

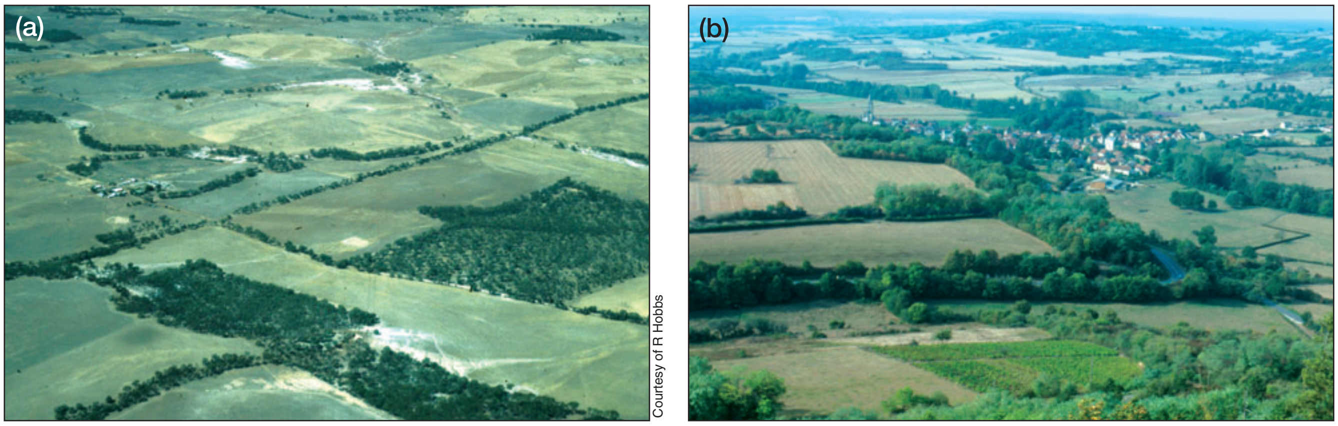


Figure 2. *Photos of agricultural landscapes that broadly correspond to different points along the continuum from coarse-grained land sparing to fine-grained, wildlife-friendly farming. (a) The wheatbelt in Western Australia is an example of a coarse-grained landscape, where land sparing is used. (b) The Loire Valley in France is an example of a landscape with an intermediate spatial grain. (c) The Coto Brus area in Costa Rica is an example of a fine-grained landscape, where wildlife-friendly farming is practiced.*

land in this region is dominated by essentially homogeneous, industrial wheat fields (Figure 2a). An example of wildlife-friendly farming occurs in the Coto Brus area in Costa Rica (Figure 2c). Industrial agriculture is virtually absent from this region, and land cover is extremely heterogeneous. Land-cover types include coffee grown in full sun, shade coffee (mostly planted among monospecific stands of shade trees), cattle pastures with scattered native trees, mixed farms, and remnant patches of native forest. A single land-use type typically covers a contiguous area of no more than 30 ha (Ricketts *et al.* 2001). Other landscapes are somewhat intermediate. For example, many traditionally farmed European landscapes have intermediate levels of heterogeneity, are characterized by variability over intermediate spatial scales, and provide habitat for a range of animals that have often co-occurred with farming operations for centuries (Figure 2b; Benton *et al.* 2003; Tscharntke *et al.* 2005). Although not every landscape will easily fit into the continuum presented in Figure 1, this simplified scheme helps to illustrate a range of options for integrating agriculture and biodiversity.

Conceptual basis

To date, different researchers have tentatively favored land sparing (Balmford *et al.* 2005; Green *et al.* 2005; Aratrakorn *et al.* 2006) or wildlife-friendly farming (Manning *et al.* 2006; Dorrough *et al.* 2007; Vandermeer and Perfecto 2007). Their preferences may reflect genuine differences between the systems studied, but they may also stem from differing scientific traditions and conceptual models of modified landscapes.

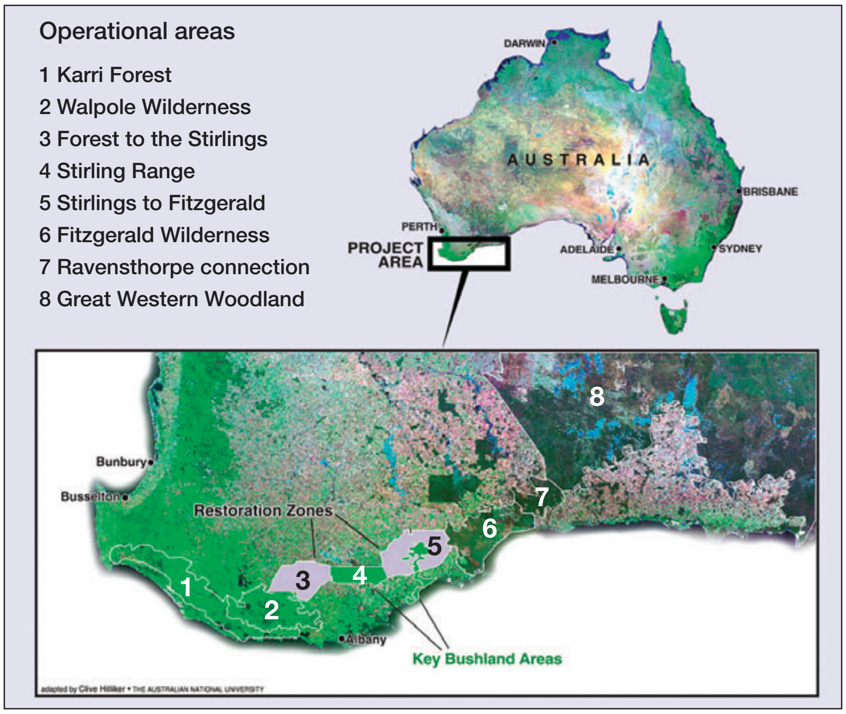
Land sparing is based on a binary view of landscapes, where islands of nature are seen as separate from human activities (Haila 2002), and ecological interactions between nature and agriculture are of minor concern (Waggoner 1996). This conceptual model originates from the equilibrium theory of island biogeography (reviewed by Haila 2002). The binary view of landscapes, combined with an emphasis on equilibria, makes the land-sparing approach highly compatible with mathematical optimization approaches that seek to allocate resources in the most efficient way (Polasky *et al.* 2005).

In contrast, wildlife-friendly farming assumes that human activities and nature co-occur within complex social–ecological systems (Berkes 2004), and interactions between nature and agriculture are of great interest (Ricketts *et al.* 2004; Tscharntke *et al.* 2005). An important but often implicit concern of advocates of wildlife-friendly farming is the long-term future of social–ecological systems. Resilience and adaptive capacity are typically given greater emphasis in this school of thought than maximum efficiency in the present moment (Holling and Meffe 1996; Tscharntke *et al.* 2005). Homogeneity is not favored for its short-term efficiency benefits; rather, it is seen as a threat to spatial and temporal variability, which is believed to be key to maintaining an ecosystem's long-term sustainability and resilience (Holling and Meffe 1996; Walker and Salt 2006).

Benefits and limitations

Recognizing the conceptual basis of land sparing and wildlife-friendly farming enables a balanced assessment of the benefits and limitations of each approach. Especially in landscapes with little species turnover, land sparing has benefits for species that are sensitive to even low-intensity agriculture (Green *et al.* 2005). It may protect ecosystems containing a near-complete assemblage of species found prior to human landscape modification, thereby maintaining high regional-scale biodiversity, at least in the short term (Myers *et al.* 2000). Conversely, land sparing can be problematic in landscapes with naturally high species turnover, because intensification anywhere is likely to result in substantial loss of species.

Wildlife-friendly farming is suitable for species that can persist in a "soft-matrix" landscape (Green *et al.* 2005), it may foster beneficial ecosystem services, and its high degree of spatial continuity may assist in the reassembly of ecological communities in response to climate change. Perhaps most importantly, the negative off-site consequences or externalities resulting from high resource inputs are typically lower in wildlife-friendly farming than in industrial agriculture (Matson and Vitousek 2006).



Courtesy of Gondwana Link Coordination Unit

Figure 3. *Schematic overview of the Gondwana Link project in southwestern Australia. The project aims to reconnect eight ecoregions, some of which are currently dominated by largely cleared agricultural land. For details, see www.gondwanalink.org.*

Balancing biodiversity and agriculture in the real world

An understanding of the conceptual basis, benefits, and limitations of land sparing and wildlife-friendly farming provides a useful starting point for considering appropriate policy priorities. However, in reality, opportunities to explicitly choose between land sparing and wildlife-friendly farming are likely to be extremely uncommon. The feasibility and appropriateness of either approach in a given landscape is affected by that landscape's inherent biophysical properties, and its historical and socioeconomic context.

First, topography affects the likelihood of either approach to be practiced. Wild-life-friendly farming is more likely to occur in landscapes with complex topography, where industrial agriculture and its associated machinery are difficult to implement. For example, the Coto Brus region in Costa Rica (Figure 2c) is too mountainous for industrial agriculture. In contrast, the wheatbelt of Western Australia (Figure 2a) is essentially flat. Topography also has an important effect on productivity gradients throughout a landscape. Complex productivity gradients are related to high species turnover, and therefore favor wildlife-friendly farming.

Second, the overall productivity of a landscape can be related to its suitability for industrial agriculture. Low-productivity environments, such as grassy woodlands in eastern Australia, are often naturally poor in nutrients. Because high-input agriculture can cause severe damage to such systems, land sparing may not be desirable in these areas (Dorrough *et al.* 2007).

Third, historical land ownership patterns can influence the degree to which agriculture is wildlife-friendly, by affecting a landscape's spatial grain, even if it is similar in topography to other areas. For example, agricultural fields in northern Europe are often very small for historical and cultural reasons, even though parts of this region are as flat as the Western Australian wheatbelt. Heterogeneity within and between fields, and vegetation alongside field margins, can effectively make some of these European landscapes "wildlife-friendly" (Benton *et al.* 2003; Tscharntke *et al.* 2005).

Fourth, socioeconomic forces influence how individual farmers choose to balance agriculture and biodiversity. The model proposed by Green *et al.* (2005) assumes that agricultural yields are necessarily lower in wildlife-friendly farming. However, relationships between yield and biodiversity can be more complex, with yield sometimes peaking at intermediate levels of biodiversity (Perfecto *et al.* 2005). In addition, yield per se may not be the most important variable from an individual farmer's economic perspective. High yields are often only achieved because of the use of costly inputs such as fertilizers and pesticides. Because of its lower cost, low-input farming can still be profitable, even if it produces a lower yield, as seen in Mexican coffee farms (Gordon *et al.* 2007) and American farms employing "holistic resource management" (Stinner *et al.* 1997).

Finally, dominant paradigms and societal preferences have an important bearing on whether land sparing or

Courtesy of T Benton and S Munson

Figure 4. *View of a dryland wheat field (right) and an adjacent plot of land replanted in perennial grasses under the Conservation Reserve Program in northeastern Colorado.*

such as organic agriculture (Hole *et al.* 2005). Similarly, subsidy payments to farmers for the provision of non-cultivated areas as wildlife habitat are increasingly used around the world (Mattison and Norris 2005). More generally, land sparing may be preferred for its efficiency, whereas wildlife-friendly farming is more likely to safeguard a landscape's adaptability to altered climatic and economic conditions (Walker and Salt 2006).

Policy guidelines for agricultural landscapes

Developing agricultural policies that effectively balance biodiversity and agriculture is no trivial task. What constitutes appropriate policy action will depend upon a range of historical and socioeconomic factors. It will also differ between landscapes with a long history of agriculture and "frontier landscapes" undergoing rapid land conversion. Yet, although the social constraints on policy development differ around the globe, the biophysical processes governing ecosystems are independent of political boundaries. Understanding biophysical relationships is therefore a logical starting point for deriving broadly applicable policy guidelines.

wildlife-friendly farming is adopted. While industrial agriculture has been the norm in many developed countries for decades, consumers are increasingly interested in "greener" products produced by wildlife-friendly farming operations,

Rather than seeing wildlife-friendly farming and land sparing as mutually exclusive options for land management, it should be recognized that both offer different, and sometimes complementary advantages. Panel 1 outlines a set of policy guidelines that draws on the strengths of both approaches, some of which are already being implemented in parts of the world. For example, the Gondwana Link project in southwestern Australia attempts to reconnect native vegetation over hundreds of kilometers, some of which is on private properties currently cleared and dominated by industrial agriculture (www.gondwanalink.org; Figure 3). Similarly, temporary fallows and revegetation activities are being encouraged in the US by the Conservation Reserve Program (www.nrcs.usda.gov/programs/crp; Figure 4). Other guide-

Panel 1. Recommended policy guidelines for agricultural landscapes

Policy guidelines for fine-grained, heterogeneous farming:

- Maintain the existing benefits from fine-grained heterogeneity and encourage agricultural practices that maintain this heterogeneity (eg maintain forest remnants, scattered trees, and crop diversity).
- Restore substantial blocks and networks of native ecosystems through measures such as community initiatives across property boundaries or strategic land acquisition. These measures will benefit species that need large areas and are sensitive to agriculture.

Policy guidelines for coarse-grained, homogeneous farming areas:

- Protect and expand large patches of native vegetation because these provide important source and refuge habitat for species sensitive to agriculture.
- Create connections between existing reserves to increase adaptive capacity in the face of climate change. Connections may be created by traditional corridors or by innovative management strategies within agricultural lands, such as temporary fallows (Bengtsson *et al.* 2003).
- Increase landscape heterogeneity and reduce the grain size of the landscape. Appropriate measures may include diversification of cropping and other land-use activities, the sub-division of fields to create a larger number of smaller fields, the establishment of vegetation along linear features, such as field boundaries and roads, and the enhancement of vegetation structure within agricultural areas.

Policy guidelines for frontier landscapes undergoing rapid land conversion for agriculture:

- Avoid ad-hoc and unregulated intensification, which can lead to "death by a thousand cuts".
- Actively plan for a mix of land sparing and wildlife-friendly farming where appropriate, taking into account both ecological and social factors. Agricultural intensification without conservation planning is a major threat to biodiversity (Fearnside 2002).
- Create reserves around known regional-scale centers of biodiversity, by identifying priority hot spots, for example (Myers *et al.* 2000).

lines listed in Panel 1 are rarely considered – for example, we are unaware of any programs that explicitly encourage the reduction of grain size in agricultural landscapes.

To continue making progress, creative measures will be needed to translate the full set of guidelines into on-the-ground action. Such measures will require engaging stakeholders and politicians, and may include local networks of landholders, new regulations, incentive payments, or the acquisition of land to add to existing reserves. Different tools will suit different regions. In frontier landscapes, the development of appropriate measures is a serious challenge, because institutions of governance and civil society that can oversee and manage pressure for land-use intensification are often poorly developed.

Our broad policy guidelines (Panel 1) are based on a balanced assessment of relevant scientific traditions and they acknowledge the importance of complex social–ecological processes. When used together, as part of an integrated approach, land sparing and wildlife-friendly farming can offer complementary benefits to biodiversity conservation.

Acknowledgements

JF acknowledges support by the Australian Academy of Science. The authors thank J Dorrough, W Falcon, P Kareiva, P Matson, S Mazouz, R Naylor, R Pringle, K Rawlings, and P Smith for valuable comments and discussion.

References

Aratrakorn S, Thunhikorn S, and Donald PF. 2006. Changes in bird communities following conversion of lowland forest to oil palm and rubber plantations in southern Thailand. *Bird Conserv Int* **16**: 71–82.

Balmford A, Green RE, and Scharlemann JPW. 2005. Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. *Global Change Biol* **11**: 1594–1605.

Bengtsson J, Angelstam P, Elmqvist T, *et al.* 2003. Reserves, resilience, and dynamic landscapes. *Ambio* **32**: 389–96.

Benton TG, Vickery JA, and Wilson JD. 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol Evol* **18**: 182–88.

Berkes F. 2004. Rethinking community-based conservation. *Conserv Biol* **18**: 621–30.

Dorrough J, Moll J, and Crosthwaite J. 2007. Can intensification of temperate Australian livestock production systems save land for native biodiversity? *Agric Ecosys Environ.* **121**: 222–32.

Eggleton P, Vanbergen AJ, Jones DT, *et al.* 2005. Assemblages of soil macrofauna across a Scottish land-use intensification gradient: influences of habitat quality, heterogeneity, and area. *J Appl Ecol* **42**: 1153–64.

Fearnside PM. 2002. Can pasture intensification discourage deforestation in the Amazon regions of Brazil? In: Wood CH and Pozzo R (Eds). Deforestation and land use in the Amazon and Pantanal regions of Brazil. Gainesville, FL: University of Florida Press.

Fischer J, Lindenmayer DB, and Manning AD. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for off-reserve conservation. *Front Ecol Environ* **4**: 80–86.

Foley JA, DeFries R, Asner GP, *et al.* 2005. Global consequences of land use. *Science* **309**: 570–74.

Gordon C, Manson R, Sundberg J, and Cruz-Angon A. 2007. Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystem. *Agric Ecosys Environ* **118**: 256–66.

Green RE, Cornell SJ, Scharlemann JPW, and Balmford A. 2005. Farming and the fate of wild nature. *Science* **307**: 550–55.

Haila Y. 2002. A conceptual genealogy of fragmentation research: from island biogeography to landscape ecology. *Ecol Appl* **12**: 321–34.

Harvey CA, Medina A, Sanchez DM, *et al.* 2006. Patterns of animal diversity in different forms of tree cover in agricultural landscapes. *Ecol Appl* **16**: 1986–99.

Hole DG, Perkins AJ, Wilson JD, *et al.* 2005. Does organic farming benefit biodiversity? *Biol Conserv* **122**: 113–30.

Holling CS and Meffe GK. 1996. Command and control and the pathology of natural resource management. *Conserv Biol* **10**: 328–37.

Luck GW and Daily GC. 2003. Tropical countryside bird assemblages: richness, composition, and foraging differ by landscape context. *Ecol Appl* **13**: 235–47.

Manning AD, Fischer J, and Lindenmayer DB. 2006. Scattered trees are keystone structures – implications for conservation. *Biol Conserv* **132**: 311–21.

Matson PA and Vitousek PM. 2006. Agricultural intensification: will land spared from farming be land spared for nature? *Conserv Biol* **20**: 709–10.

Mattison EHA and Norris K. 2005. Bridging the gaps between agricultural policy, land-use, and biodiversity. *Trends Ecol Evol* **20**: 610–16.

MA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: synthesis report. Washington, DC: Island Press.

Myers N, Mittermeier RA, Mittermeier CG, *et al.* 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–58.

Perfecto I, Vandermeer J, Mas A, and Pinto LS. 2005. Biodiversity, yield, and shade coffee certification. *Ecol Econ* **54**: 435–46.

Polasky S, Nelson E, Lonsdorf E, *et al.* 2005. Conserving species in a working landscape: land use with biological and economic objectives. *Ecol Appl* **15**: 1387–1401.

Population Reference Bureau. 2006. World population data sheet. www.prb.org. Viewed 29 Aug 2007.

Ragauskas AJ, Williams CK, Davison BH, *et al.* 2006. The path forward for biofuels and biomaterials. *Science* **311**: 484–89.

Ricketts TH, Daily GC, Ehrlich PR, and Fay JP. 2001. Countryside biogeography of moths in a fragmented landscape: biodiversity in native and agricultural habitats. *Conserv Biol* **15**: 378–88.

Ricketts TH, Daily GC, Ehrlich PR, and Michener CD. 2004. Economic value of tropical forest to coffee production. *Proc Natl Acad Sci USA* **101**: 12579–82.

Stinner DH, Stinner BR, and Martsolf E. 1997. Biodiversity as an organizing principle in agroecosystem management: case studies of holistic resource management practitioners in the USA. *Agric Ecosys Environ* **62**: 199–213.

Tiedje JM, Asuming-Brempong S, Nusslein K, *et al.* 1999. Opening the black box of soil microbial diversity. *Appl Soil Ecol* **13**: 109–22.

Tscharntke T, Klein AM, Kruess A, *et al.* 2005. Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. *Ecol Lett* **8**: 857–74.

Vandermeer J and Perfecto I. 2007. The agricultural matrix and a future paradigm for conservation. *Conserv Biol* **21**: 274–77.

Waggoner PE. 1996. How much land can ten billion people spare for nature? *Daedalus* **125**: 73–93.

Walker B and Salt D. 2006. Resilience thinking. Washington, DC: Island Press.